Development of a System for Ensuring Humidity in Sport Complexes

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Abstract— **One of the components and integral parts of our daily life is the climate. This is especially true in the rooms where we spend most of our time. The movement of air masses, temperature, humidity-all this affects us. Therefore, it is very important to maintain the necessary, comfortable indoor climate regime.**

In this paper, the use of a fuzzy logic controller for control humidity in sport halls. We compare performance of controllers of similar researches and their energy efficiency rate. Different humidity setting and outdoor humidity rate give different results. The results show that the proposed controller is always have lower energy consumption compared to conventional systems. Energy saving achieved is between 27 to 39%.

Keywords—humidity control, fuzzy logic, indoor, sport halls, indoor environment

I. Introduction

One of the components and integral parts of our daily life is the climate. This is especially true in the rooms where we spend most of our time. The movement of air masses, temperature, humidity-all this affects us. Therefore, it is very important to maintain the necessary, comfortable indoor climate regime [1, 2].

The article discusses a system for creating the necessary humidity in the room, which automatically maintains the specified humidity in sports halls when additional sources of drainage/irrigation appear [3]. The system is developed using a comprehensive approach based on the use of clear (for creating humidity) and fuzzy logic (for maintaining humidity). In [4], a system of indoor climate control based on fuzzy logic is described, works on indoor climatology are considered, and conclusions are drawn about the necessary climate parameters. Nevertheless, the developed model of the system for creating a comfortable climate entails another, no less important problem: achieving comfortable climate parameters and maintaining them [5-8].

II. Problem Statement

The aim of this control strategy is to design strategies by combining conventional and intelligent control technologies for indoor humidity control by using fuzzy logic based control and experimental investigation, and to show the potential direction for improving athletes' comfort in an indoor environment [9]. A humidity controllers will be designed to analyze the potential of the proposed system. Figure 1 demonstrates the experimental area.

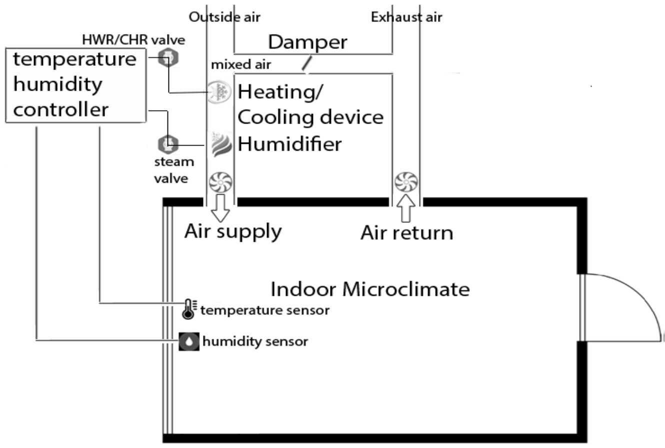


Fig. 1. Experimental area

Figure 2 illustrates the input and output parameters of the proposed system.

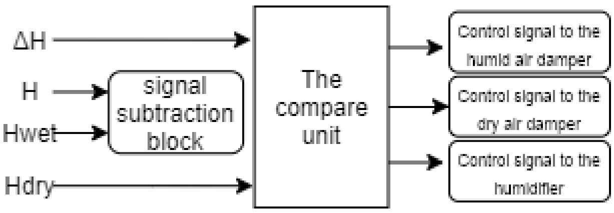


Fig. 2. Input and output parameters

III. Applying Fuzzy and Clear Logic to the Specific Task of Creating and Maintaining the Necessary Humidity in the Room

A. Humidity Control System

Let's describe the technical side of the system-supply ventilation channels. The VL channel takes air from a wetter environment; the DRY channel takes air from a drier environment [10-12]. The system specifically includes these two channels, because this allows in some cases to abandon the forced dehumidification/irrigation of the air with water vapor, which in turn leads to a reduction in energy consumption. Next, let's look at the algorithm of the system [13].

The humidity generation system works as follows:

when a signal ΔU (a signal sent from the climate control system [14-17]) occurs-a signal of changes in humidity in the room, greater than or less than zero, the system subtracts the values of uu (humidity in the room at the moment) and UVL (humidity in the ventilation channel of the overhead line in the signal subtraction block);

based on the result of the subtraction operation and ΔU, the system operation algorithm is selected, humidity changes are monitored, and control signals are sent by the dampers of wet, dry air and humidifier

The algorithms of the system operation are described below.

If ΔU < 0 and the result of the process execution by the subtraction block < 0, then the command K1 is executed: the valve DRY is fully open; the valve BL is completely closed until the condition Y1 is met:

$$U = U_{indoor} - \Delta U + 5\% \tag{1}$$

After the condition Y1 is met, the command K2 is executed: the VL Flap is open by 80 %; the DRY flap is open by the value obtained by the formula:

$$b = 0.8(H - H_{indoor})(H - H_{dry} - \Delta H) \tag{2}$$

If ΔU < 0 and the result of the process by the subtraction block > 0, the command K1 is executed: the valve DRY is fully open; the valve BL is completely closed until the condition Y1: formula (1) is met. After the condition Y1 is met, the command K2 is executed: the VL flap is fully open; the DRY flap is fully closed; the humidifier is switched on to the value obtained by the formula:

$$b = (H_{indoor} - \Delta H) - 0.8H_{wet} \tag{3}$$

If ΔU > 0 and the result of the process execution by the subtraction block < 0, then the command K1 is executed: the VL flap is fully open; the DRY flap is completely closed until the condition Y1 is met:

$$H = (H_{indoor} + \Delta H) - 5\% \tag{4}$$

After the condition Y1 is met, the command K2 is executed: the VL flap is open by 80 %; the DRY flap is open by the value obtained by the formula:

$$b = (H_{indoor} + \Delta H) - 0.8H_{wet} \tag{5}$$

You should pay attention to where formula (2), (4). Humidity depends on the air mass passing through the pipe per unit time, and hence the volume of air masses and the amount of water vapor in the air [18]. If two pipes (DRY and overhead) converge into one volume, and the cross-sectional area of the pipes is the same, then the final humidity can be found by the formula:

$$H_{indoor} = \frac{(a \cdot H_{wet} + b \cdot H_{dry})}{a + b} \tag{5}$$

where a, b are the percentages of the opening values of the corresponding dampers. The valve of the overhead line channel is specially opened by 80 % in order to be able to control this parameter in the future.

Thus, we have described the system for creating humidity. However, it is important not only to set the humidity to a certain level, but also to be able to correctly and effectively maintain it in the selected range [14]. The humidity maintenance system will be described below.

B. The System of maintenance of humidity in the room

The described system is constructed similarly to the indoor climate control system [19-21]. But we will divide it into a humidity management system, where humidity changes only in the room, and a humidity management system, where humidity changes in the channels. We will consider only the first system, because it clearly shows all the advantages of H-logic in solving this problem.

In the system only two input signals: change in humidity and difference of humidity in the WET channel and the room (this last selection is not random, because there is no need to consider the moisture content in both channels and important difference between the humidities); the output signals are represented with the following parameters – percentage of value of opening of the damper DRY, percentage of value of opening of valve VL, a percentage of the value of the humidifier.

The process is divided into stages of fuzzification, building a database of rules, and defuzzification.

C. Fuzzification

In the process of fuzzification as a term – sets of linguistic variables we will use sets: the change in humidity – Chip with the membership functions depicted in Fig. 3; the difference of moisture in channel WET and in the room of iraz with the membership functions depicted in Fig. 4; the percentage of opening of the damper DRY – Vсх with the membership functions depicted in Fig. 5; the percentage of opening of valve VL – Vвл with the membership functions depicted in Fig. 6; the percentage of the humidifier/dehumidifier – Vув with the membership functions depicted in Fig. 7.

Next, we will build a database of fuzzy linguistic rules for the operation of the system the following database of rules is shown below in the Table I.

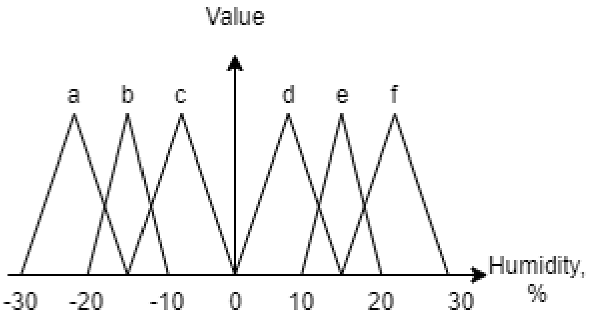


Fig. 3. Graphs of membership functions for the term of the linguistic variable "change in humidity in the room": a-large decrease; b-average decrease; c-small decrease; d-small increase; e-average increase; f-large increase

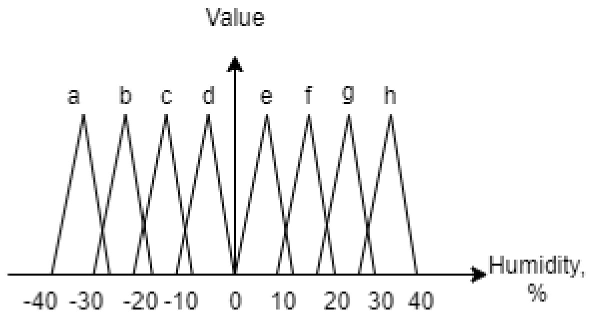


Fig. 4. Graphs of membership functions for the term of the linguistic variable "humidity difference in the overhead line channel and the room": a-open a lot; b-open medium; c-open little; d-close little; e-close medium; f-close a lot

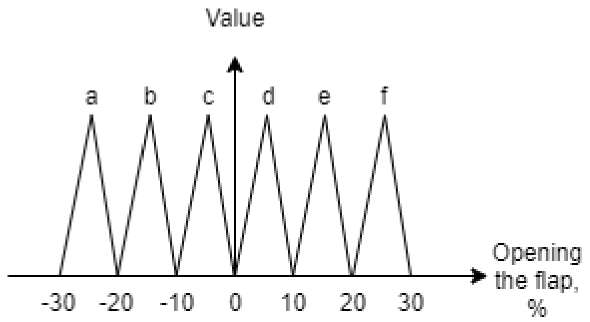


Fig. 5. Graphs of membership functions for the term of the linguistic variable "percentage of opening the flap DRY": a-open a lot; b-open average; c-open little; d-close little; e-close average; f-close a lot

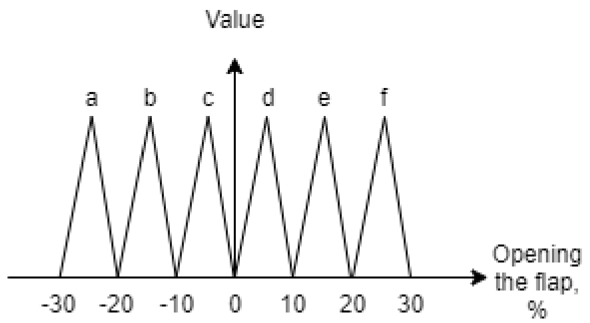


Fig. 6. Graphs of membership functions for the term of the linguistic variable "percentage of opening of the VL flap": a-open a lot; b-open an average; c-open a little; d-close a little; e-close an average; f-close a lot

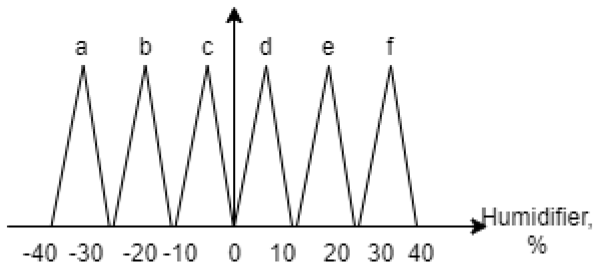


Fig. 7. Graphs of membership functions for the term of the linguistic variable "percentage of humidifier/dehumidifier inclusion": a-reduce a lot; b-decrease average; c-decrease a little; d-add a little; e-add medium; f-add a lot

TABLE I. RULE BASE

ΔU_{indoor}	ΔU_{dif}	$\%U_{dry}$	$\%U_{wet}$	Humidify
GR	LL	CL	-	AMANY
GR	LA	CL	-	AMANY
GR	aLL	CL	-	AMANY
GR	MA	CL	-	AMANY
GR	BL	-	-	AMANY
GR	BH	-	-	AL
GR	BA	CL	-	AL
GR	BG	CL	-	-
AR	LG	-	-	AM
AR	LA	CL	-	AM
AR	LL	-	-	AM
AR	MA	-	-	AM
AR	BL	-	-	AM
AR	BH	CL	-	-
AR	BA	CL	-	RL
AR	BG	CL	-	RA
SR	LG	-	-	DH
SR	LA	-	-	DH
SR	LL	-	-	AM
SR	MA	-	-	AL
SR	BL	CL	-	AL
SR	BH	CL	-	-
SR	BA	CL	-	RL
SR	BG	CL	-	RA
SI	LG	-	-	RL
SI	LA	-	-	RL
SI	LL	-	-	RL
SI	MA	-	-	RL

SI	BL	-	CL	-
SI	BH	CL	CL	-
SI	BA	CME	CL	-
SI	BG	CME	CME	-
AI	LG	-	-	RA
AI	LA	-	-	RA
AI	LL	-	-	RA
AI	MA	-	-	RA
AI	BL	CL	CL	-
AI	BH	CME	CL	-
AI	BA	CME	CME	-
AI	BG	CM	CME	-
BI	LG	-	-	RG
BI	LA	-	-	RG
BI	LL	-	-	RG
BI	MA	-	-	RG
BI	BL	-	CME	-
BI	BH	CL	CME	-
BI	BA	CL	CM	-
BI	BG	CME	CM	-

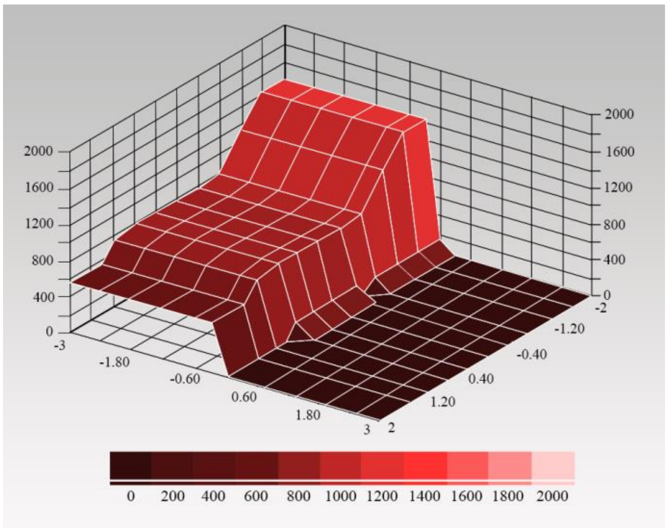
Note to table: ΔU_{indoor}, ΔU_{dir} – changes in humidity and difference in moisture in the channel HUMID and indoor area; $\%U_{dry}$, $\%U_{wet}$ – percentage of flap opening channels DRY and WET; Moisture – percentage of humidifier is; GR – great reduction; AR – average reduction; SR – a small reduction; SG – small growth; AI – average increase; BI – a big increase; CG – close great (many); CM – close medium; CL – close a little; RG – reduce great (many) RA – reduce average; RL – reduce a little; AM – add medium; AL – add a little; AMany – add many; LL – less lot; LM – less medium; aLL – a little less;

D. Defuzzification

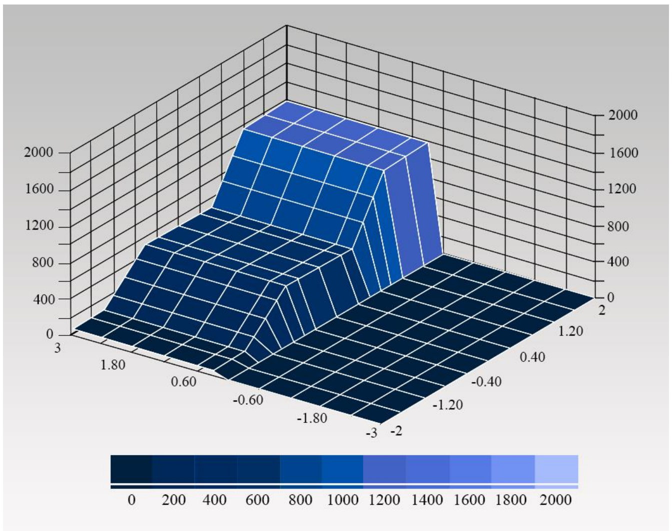
The defuzzification process is similar to the climate control process [22]. Below are the graphs of dependencies of the output parameters on the initial data of the defuzzification process.

IV. Experiement Results

The three-dimensional surface of the fuzzy inference for controlled heating / cooling devices, depending on the room conditions parameters is shown in Fig. 8.



a. The graph of the change in the percentage inclusion of a humidifier/dehumidifier from changes in humidity and difference of moisture in the channel WET and the room



b. The graph of the change in the percentage of flap opening DRY from changes in humidity and difference of moisture in the channel DRY and the room

Fig. 8. Three dimensioned surface of fuzzy logic for humidity control system

When we use the proposed system, the humidity rate changes between 30% and 40% (Fig. 9), that is comfort humidity.

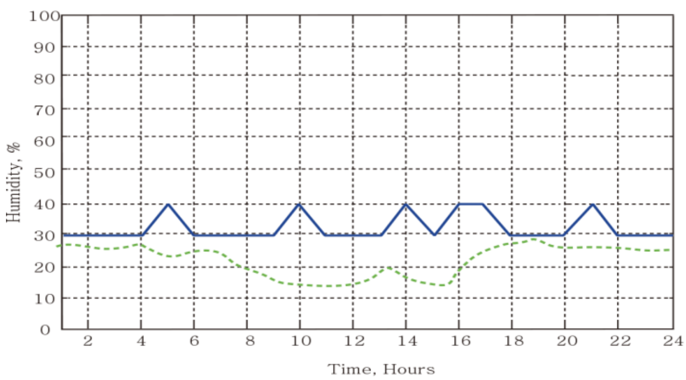


Fig. 9. Relative humidity set points with and without multi objective genetic algorithm

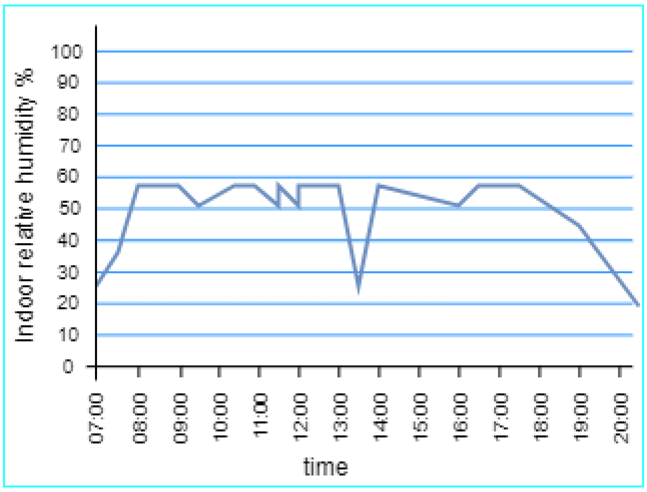


Fig. 10. Relative humidity set points with and without multi objective genetic algorithm

Fig. 10 shows the RH changes for one day in the room. The initial RH is about 20%, the humidity level in the room rises quickly above 30%, and then adjusts to the set value. During working hours, from 9:00 to 18:00, relative humidity in the premises is maintained between 50–60%. From this it follows that the temperature curve inside the room is stable and there are no abrupt changes. This means that the proposed humidity regulator controls the RH in the room well.

V. Discussion

Analysis of graphs and experiments conducted on subjects of different ages showed that the system controls all output signals at certain input signals so that the user of the system is comfortable in the room. This management is effective in achieving the goal of reducing time by 10 % and reducing energy consumption by 10 %. The main control of the humidity is due to the operation of the humidifier/dehumidifier in the whole area of changes in humidity and difference of moisture between the channel WET and also the region where the input variables have positive values, where the main change in humidity is due to the dampers channels VL and CL. This control method is chosen for reasons of speed of reaching the required regulation.

The article describes a workable system built using simple, intuitive rules, which allows the developer to quickly and effectively achieve results in building control systems using fuzzy logic.

We highlight the advantages of using the proposed method in building control systems:

1. Easy to develop: the system is built on intuitive rules with minimal knowledge of processes

2. Even with a fairly approximate selection of term sets of input / output variables and constructions, their accessory functions, the system gives an acceptable result for proper operation.

3. The system includes a minimum of necessary rules

4. The presence of microprocessors with embedded methods of fuzzy logic allows you to implement these systems.

5. The control System has the property of complexity and is more efficient than existing ones, since it uses clear and fuzzy logic for control, which determines the advantage of speed and efficiency of information processing and modular construction of the final hardware. The latter is an indisputable advantage in the development of hardware for this system.

6. The system provides the conditions for the cast to integer values. This greatly simplifies the operation of its hardware implementation.

Conclusion

In Europe, on average, buildings consume 41% of the total primary energy, most of which is spent on heating, ventilation, air conditioning, and lighting. To ensure the process of performance and energy monitoring, more buildings are beginning to use the building management system (BMS). These systems also simplify the development and implementation of these systems, which increases the energy efficiency and the quality of the indoor environment of the building.

In this paper, the use of a fuzzy logic controller for sport complexes were considered. We compare performance of controllers of similar researches and their energy efficiency rate. Different humidity setting and outdoor humidity rate give different results. The results show that the proposed controller is always have lower energy consumption compared to conventional systems. Energy saving achieved about 10%.

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